

FORM PTO-1390 (Modified)  
(REV 11-2000)

U.S. DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

ATTORNEY'S DOCKET NUMBER

## TRANSMITTAL LETTER TO THE UNITED STATES

217694US2PCT

DESIGNATED/ELECTED OFFICE (DO/EO/US)

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR

CONCERNING A FILING UNDER 35 U.S.C. 371

10/031341

INTERNATIONAL APPLICATION NO.

PCT/FR00/02142

INTERNATIONAL FILING DATE

26 July 2000

PRIORITY DATE CLAIMED

27 July 1999

TITLE OF INVENTION

METHOD FOR OPTICALLY PUMPING A LIGHT AMPLIFYING MEDIUM AND AN OPTICAL PUMPING  
MODULE FOR IMPLEMENTING THIS METHOD

APPLICANT(S) FOR DO/EO/US

DUPUY Philippe

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (24) indicated below.
4. ☒ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
  - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
  - b. ☒ has been communicated by the International Bureau.
  - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
  - a. ☒ is attached hereto.
  - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
  - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
  - b. ☐ have been communicated by the International Bureau.
  - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
  - d. ☒ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

## Items 13 to 20 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
14. ☐ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☒ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

Notice of Priority/ Drawings (3 sheets)

PCT/IB/304

PCT/IB/308

Form PTO-1449

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR 1.53) <div style="font-size: 2em; font-weight: bold; text-align: center;">10/031341</div>		INTERNATIONAL APPLICATION NO. PCT/FR00/02142		ATTORNEY'S DOCKET NUMBER 217694US2PCT	
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24. The following fees are submitted: <b>BASIC NATIONAL FEE ( 37 CFR 1.492 (a) (1) - (5) ) :</b> <div style="display: flex; justify-content: space-between;"> <div style="width: 80%;"> <input type="checkbox"/> Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO .....  <input checked="" type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO .....  <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO .....  <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) .....  <input type="checkbox"/> International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) .....           </div> <div style="width: 15%; text-align: right;">             \$1040.00              \$890.00              \$740.00              \$710.00              \$100.00           </div> </div> <div style="text-align: right; margin-top: 10px;"> <b>ENTER APPROPRIATE BASIC FEE AMOUNT =</b>              \$890.00           </div>				<b>CALCULATIONS PTO USE ONLY</b>	
Surcharge of \$130.00 for furnishing the oath or declaration later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).				\$0.00	
CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	12 - 20 =	0	x \$18.00	\$0.00	
Independent claims	2 - 3 =	0	x \$84.00	\$0.00	
Multiple Dependent Claims (check if applicable). <input type="checkbox"/>				\$0.00	
<b>TOTAL OF ABOVE CALCULATIONS =</b>				<b>\$890.00</b>	
<input type="checkbox"/> Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.				\$0.00	
<b>SUBTOTAL =</b>				<b>\$890.00</b>	
Processing fee of \$130.00 for furnishing the English translation later than <input type="checkbox"/> 20 <input type="checkbox"/> 30 months from the earliest claimed priority date (37 CFR 1.492 (f)).				\$0.00	
<b>TOTAL NATIONAL FEE =</b>				<b>\$890.00</b>	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) (check if applicable). <input type="checkbox"/>				\$0.00	
<b>TOTAL FEES ENCLOSED =</b>				<b>\$890.00</b>	
				Amount to be: refunded	\$
				charged	\$

a. ☒ A check in the amount of \$890.00 to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. \_\_\_\_\_ in the amount of \_\_\_\_\_ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 15-0030. A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

*Surinder Sachar*

\_\_\_\_\_  
SIGNATURE

**Marvin J. Spivak**  
\_\_\_\_\_  
NAME


**24,913**  
\_\_\_\_\_  
REGISTRATION NUMBER

Jan 18 2002  
\_\_\_\_\_  
DATE

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Surinder Sachar  
Registration No. 34,423



22850

Docket No. 217694US2PCT

IN RE APPLICATION OF: Philippe DUPUY

SERIAL NO: New U.S. PCT Application (Based on PCT/FR00/02142)

FILED: 26 July 2000

FOR: METHOD FOR OPTICALLY PUMPING A LIGHT AMPLIFYING MEDIUM AND AN OPTICAL PUMPING MODULE FOR IMPLEMENTING THIS METHOD

ASSISTANT COMMISSIONER FOR PATENTS  
WASHINGTON, D.C. 20231

SIR:

Transmitted herewith is an amendment in the above-identified application.

- ☒ No additional fee is required
- ☐ Small entity status of this application under 37 C.F.R. §1.9 and §1.27 is claimed.
- ☒ Additional documents filed herewith: English Translation of Specification/ Drawings (3 sheets)/ Check for \$890  
PCT/IB/304/International Search Report/ Form PTO-1449/ Information  
Disclosure Statement/ PCT/IB/308/Request for Priority/ PCT Transmittal Letter

The Fee has been calculated as shown below:

CLAIMS	CLAIMS REMAINING		HIGHEST NUMBER PREVIOUSLY PAID	NO. EXTRA CLAIMS	RATE	CALCULATIONS
TOTAL	12	MINUS	20	0	× \$18 =	\$0.00
INDEPENDENT	2	MINUS	3	0	× \$84 =	\$0.00
		<input type="checkbox"/> MULTIPLE DEPENDENT CLAIMS			+ \$280 =	\$0.00
		TOTAL OF ABOVE CALCULATIONS				\$0.00
		<input type="checkbox"/> Reduction by 50% for filing by Small Entity				\$0.00
		<input type="checkbox"/> Recordation of Assignment			+ \$40 =	\$0.00
		TOTAL				\$0.00

- ☐ A check in the amount of \_\_\_\_\_ is attached.
- ☒ Please charge any additional Fees for the papers being filed herewith and for which no check is enclosed herewith, or credit any overpayment to deposit Account No. 15-0030. A duplicate copy of this sheet is enclosed.
- ☒ If these papers are not considered timely filed by the Patent and Trademark Office, then a petition is hereby made under 37 C.F.R. §1.136, and any additional fees required under 37 C.F.R. §1.136 for any necessary extension of time may be charged to Deposit Account No. 15-0030. A duplicate copy of this sheet is enclosed.

OBLON, SPIVAK, McCLELLAND,  
MAIER & NEUSTADT, P.C.

*Surinder Sachar*

Marvin J. Spivak  
Registration No. 24,913

Surinder Sachar  
Registration No. 34,423



22850

Customer Number 22850  
Tel. (703) 413-3000  
Fax. (703) 413-2220  
(OSMMN 10/01)

217694US

10/031341  
531 Rec'd PCT/PTL 18 JAN 2002

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

IN RE APPLICATION OF :  
PHILIPPE DUPUY : ATTN: APPLICATION DIVISION  
SERIAL NO: NEW U.S. PCT APPLN :  
(Based on PCT/FR00/02142)  
FILED: HEREWITH :  
FOR: METHOD FOR OPTICALLY  
PUMPING A LIGHT AMPLIFYING  
MEDIUM AND AN OPTICAL  
PUMPING MODULE FOR  
IMPLEMENTING THIS METHOD

PRELIMINARY AMENDMENT

ASSISTANT COMMISSIONER FOR PATENTS  
WASHINGTON, D.C. 20231

SIR:

Prior to a first examination on the merits, please amend the above-identified application as follows:

IN THE CLAIMS

Please cancel Claims 1-12 without prejudice.

Please add new Claims 13-24 as follows:

13. (New) A method for optically pumping a light amplifying medium, wherein at least one light source is used for optically pumping the amplifying medium and the amplifying medium is encircled by a reflector, a wall of the reflector is configured to reflect the light from the source, wherein the reflector is partly or totally diffusive and a beam directly stemming from the source is sent towards the wall of the reflector so that this beam

undergoes successive partly or totally diffusive reflections thereon and the amplifying medium is placed out of this beam directly stemming from the source so that this amplifying medium is optically pumped by the sole light reflected by the wall of the partly or totally diffusive reflector.

14. (New) An optical pumping module comprising a light amplifying medium, at least one light source for optically pumping the amplifying medium and a reflector which encircles the amplifying medium and the wall of the reflector is configured to reflect light from the source, wherein the reflector is partly or totally diffusive and the source is orientated so as to send a beam directly stemming from this source towards the wall of the reflector so that this beam undergoes successive partly or totally diffusive reflections thereon and the amplifying medium is placed out of this beam directly stemming from the source so that this amplifying medium is optically pumped by the sole light reflected by the wall of the partly or totally diffusive reflector.

15. (New) The module according to claim 14, wherein the amplifying medium forms a cylindrical rod with a substantially circular base, the light source is for transverse optical pumping of this medium, and the wall of the reflector forms a cylinder with generatrices parallel to an axis of the amplifying medium.

16. (New) The module according to claim 15, wherein the reflector has substantially a same length as the amplifying medium.

17. (New) The module according to claim 15, wherein the base of the cylinder formed by the wall of the reflector is selected from substantially regular polygons, ellipses, and circles.

18. (New) The module according to claim 15, wherein the light source is a light emitter and this light emitter is selected from a laser diode, a laser diode array, a row of laser

diode arrays, a stack of laser diode arrays, and a combination of the row and the stack, the arrays being parallel to generatrices of the cylinder formed by the wall of the reflector.

19. (New) The module according to claim 15, further comprising several blocks, each block comprising a planar face, configured to reflect the light from the source in a partly or totally diffusive way, wherein the base of the cylinder formed by the wall of the reflector is a substantially regular polygon, this wall thereby comprising several sides, each of the sides being formed by two respective planar faces of two adjacent blocks.

20. (New) The module according to claim 19, wherein the light source is placed in a gap formed between two adjacent blocks in such a way that the light emerges from a space formed between the respective planar faces of these two blocks and reaches the wall of the reflector.

21. (New) The module according to claim 18, further comprising several blocks, each block comprising a planar face, configured to reflect the light from the source in a partly or totally diffusive way, wherein the base of the cylinder formed by the wall of the reflector is a substantially regular polygon, this wall thereby comprising several sides, each of the sides being formed by two respective planar faces of two adjacent blocks,

wherein the light source is placed in a gap formed between two adjacent blocks in such a way that the light emerges from a space formed between the respective planar faces of these two blocks and reaches the wall of the reflector,

wherein both blocks are electrically conducting and the laser diode or the laser diode arrays are electrically powered by these two blocks.

22. (New) The module according to claim 14, wherein the light source is a light emitter.

23. (New) The module according to claim 14, wherein the light source is a light propagation means, one end of which is for receiving the light from a light emitter and another end of which is for sending this light towards the wall of the reflector.

24. (New) The module according to claim 14, wherein the reflector is quasi-lambertian.

#### IN THE ABSTRACT OF THE DISCLOSURE

Please delete the original Abstract page 17 in its entirety and insert therefor:

#### ABSTRACT

A method for optically pumping a light-amplifying medium and an optical pumping module for implementing the method. At least one light source is used for pumping the amplifying medium and this medium is encircled by a reflector, the wall of which diffusely reflects this light. A beam directly stemming from the source is sent towards the wall so that it undergoes diffusive reflections and the amplifying medium is placed out of this beam so that it may be pumped by the sole light diffused by the wall. The method and apparatus can be particularly applied to cutting, welding lasers and those for treating the surface of materials.

#### REMARKS

Favorable consideration of the present application, as presently amended, is respectfully requested.

The present preliminary amendment is submitted to place the above-identified application in more proper format under United States practice.

By the present preliminary amendment, original Claims 1-12 are cancelled and new Claims 13-24 are presented for examination. New Claims 13-24 are deemed to be self-evident from the original disclosure, including original Claims 1-12, and thus are not deemed to raise any issues of new matter.

A new Abstract believed to be in more proper format under United States practice is also submitted herein.

The present application is believed to be in condition for a full and thorough examination on the merits. An early and favorable consideration of the present application is hereby respectfully requested.

Respectfully submitted,

OBLON, SPIVAK, McCLELLAND,  
MAIER & NEUSTADT, P.C.



Gregory J. Maier  
Attorney of Record  
Registration No. 25,599  
Surinder Sachar  
Attorney of Record  
Registration No. 34,423



**22850**

(703) 413-3000  
Fax No.: (703)413-2220  
GJM/SNS:kst  
I:\atty\SNS\217694us-pr.wpd  
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**Marked-Up Copy**

Serial No:

Amendment Filed on:

1-18-2002IN THE CLAIMS

Claims 1-12 (Canceled).

Claims 13-24 (New).

IN THE ABSTRACT OF THE DISCLOSURE

--Abstract (New).--

3/PRTS

10/031341

<sup>1</sup> 531 Rec'd PGT/PTC 18 JAN 2002

METHOD FOR OPTICALLY PUMPING A LIGHT AMPLIFYING MEDIUM  
AND AN OPTICAL PUMPING MODULE FOR IMPLEMENTING THIS  
METHOD

TECHNICAL FIELD

The present invention relates to a method for optically pumping a light-amplifying medium as well as to an optical pumping module for implementing this method.

5 A laser based on the invention finds industrial applications, notably in the following fields: welding, cutting, surface treatment of materials, and labelling of objects.

10 It may also find applications in the medical field.

STATE OF THE ART

15 It is known that a laser essentially comprises an amplifying medium and two mirrors forming a resonant cavity, the amplifying medium being placed between these two mirrors.

The energy required for operating a laser may be provided to the amplifying medium, electrically, chemically or optically.

20 In the present invention, we are interested in the third way, i.e. in what is called the optical pumping of the amplifying medium.

25 The distribution of pumping light in the amplifying medium should be as homogeneous as possible to reduce the effects which limit the performances of the laser.

Now, if nothing is specifically undertaken in this direction, the distribution of this pumping light is

generally inhomogeneous and it frequently has a maximum on the side of the source of this light.

Right now, let us specify that the invention relates to a method for making this distribution  
5 homogeneous.

It is known that the amplifying medium of a laser absorbs the whole or a part of the pumping power and re-emits a certain amount of it as stimulated emission, the remainder of the absorbed power is transformed into  
10 heat. This stimulated emission is called the "laser effect".

The absorption of the pumping power follows an exponential law (the Beer-Lambert law) which is expressed by a larger absorbed power on the portion (or  
15 the portions) of the amplifying medium near the pumping source. This generates pumping inhomogeneities: the absorbed power is not the same in all points of the amplifying medium.

The pumping power variations in different points  
20 of this medium in turn generate local variations of the refractive index which induce deformations of the wave front of the emitted laser beam.

The ultimate consequence of these pumping inhomogeneities is a limitation of the quality of this  
25 laser beam. In particular, the deformation of the wave front may limit the extracted power from the laser and increase the divergence of the laser beam.

In the particular case of a solid amplifying medium in the shape of a rod, it is known that these  
30 drawbacks are overcome by pumping this medium longitudinally. To do this, the light flux from one or more light sources, for example laser diodes, is focussed on one of the faces of the rod.

With this technique, a homogeneous distribution of the pumping may be obtained but it is not adapted to lasers with very high average power output because of the thermal stress problems of the end of the amplifying medium. In fact this technique is especially adapted to transverse monomode lasers with moderate average power output.

When it is desired to build a laser with high average power output, a known transverse technique is preferably used. A finite number of laser diodes are then positioned radially around the amplifying medium.

This is schematically illustrated by Fig. 1 where in a sectional view, a laser rod 2 is seen placed in a sapphire sleeve 4.

The space between the rod 2 and the sleeve 4 forms a cooling channel 6. Three laser diodes 8 are placed at  $120^\circ$  from one another around the sleeve 4 and are separated from each other by copper spacers 10.

Each diode 8 emits a light beam for optical pumping in the direction of rod 2 and this beam is focussed on the rod via a cylindrical lens 12.

In this known transverse pumping technique, each diode in fact, only illuminates a limited portion of the amplifying medium and the pumping homogeneity which may then be obtained directly, depends on the degree of symmetry of the diodes-rod system.

The more diodes, more the ideal axisymmetric case is approached. Now, in practice, mechanical stresses cause the number of diodes to be frequently limited to 3 or 5.

#### DESCRIPTION OF THE INVENTION

The object of the present invention is a method

for optically pumping a light-amplifying medium as well as an optical pumping module, which enable this pumping power to be distributed homogeneously, may be used for forming a laser, regardless of the intended power for this laser, and do not require a large number of pumping light sources.

Specifically, the present invention relates to a method for optically pumping a light-amplifying medium, wherein at least one light source is used for optically pumping the amplifying medium and this amplifying medium is encircled by a reflector, the (simple or multiple) wall of which is able to reflect the light of the source, this method being characterized in that the reflector is partly or totally diffusive and in that the beam directly stemming from the source is sent towards the wall of the reflector so that this beam undergoes successive partly or totally diffusive reflections and the amplifying medium is placed out of this beam directly stemming from the source so that the amplifying medium is optically pumped by the sole light reflected by the wall of the partly or totally diffusive reflector.

The invention also relates to an optical pumping module for a light amplifying medium, comprising at least a light source for optically pumping the amplifying medium and a reflector which encircles this amplifying medium and the (simple or multiple) wall of which is able to reflect the light of the source, this module being characterized in that the reflector is partly or totally diffusive and in that the source is orientated so as to send the beam directly stemming from this source towards the wall of the reflector so that this beam undergoes successive partly or totally

diffusive reflections and in that the amplifying medium is placed out of this beam directly stemming from the source so that this amplifying medium is optically pumped by the sole light reflected by the wall of the reflector.

According to a preferred embodiment of the module, object of the invention, the amplifying medium forms a cylindrical rod with a substantially circular base, the light source is for transverse optical pumping of this medium and the wall of the reflector forms a cylinder with its generatrices parallel to the axis of the amplifying medium.

Preferably, the reflector has substantially the same length as the amplifying medium.

The base of the cylinder formed by the wall of the reflector may for example be selected from substantially regular polygons, ellipses and circles.

The light source may be a light emitter.

This light emitter may be selected from a laser diode, a laser diode array, a row of laser diode arrays, a stack of laser diode arrays and a combination of this row and this stack, this (or these) array(s) being parallel to the generatrices of the cylinder which are formed by the wall of the reflector.

The module, object of the invention, may further comprise several blocks, wherein each block comprises a plane face, able to reflect the light of the source in a partly or totally diffusive way, wherein the base of the cylinder formed by the wall of the reflector being a substantially regular polygon, wherein this wall thus comprises several sides, each of the latter being formed by two respective planar faces of two adjacent blocks.

The light source may be placed in a gap formed between two adjacent blocks in such a way that the light emerges from the space thereby formed between the respective planar faces of these two blocks and reaches the wall of the reflector.

According to a particular embodiment of the invention, both blocks are electrically conducting and the laser diode or the laser diode array(s) are electrically powered via both of these blocks.

Instead of being a light emitter, the light source may be a light propagation means, one end of which is for receiving the light from a light emitter and the other end of which is for sending this light towards the wall of the reflector. Preferably, the reflector is quasi-lambertian.

#### SHORT DESCRIPTION OF THE DRAWINGS

The present invention will be better understood upon reading the description of exemplary embodiments given hereafter, purely as an indication, and by no means as a limitation, with reference to the appended drawings wherein:

- Fig. 1 schematically illustrates a known technique for transverse optical pumping of a light-amplifying medium and it has already been described,

- Fig. 2 schematically illustrates the principle of the present invention,

- Fig. 3 is a schematic sectional view of a first particular embodiment of the optical pumping module, object of the invention, using a reflector with a cylindrical wall and a square base,

- Fig. 4 is a schematic sectional view of a second particular embodiment of the optical pumping

module, object of the invention, using a diffusive reflector with a cylindrical wall and a circular base, and

- Fig. 5 is a schematic sectional view of a third particular embodiment of the optical pumping module subject of the invention, using a diffusive reflector with a cylindrical wall and a polygonal base.

#### DETAILED DISCUSSION OF THE PARTICULAR EMBODIMENTS

10 An optical pumping module according to the invention is schematically illustrated as a sectional view in Fig. 2 and comprises a light-amplifying medium 14 and at least a light source 16, for example a laser diode, this source being preferably quasi point-like.

15 The source 16 is provided in order to provide light able to optically pump the amplifying medium 14.

The module illustrated in Fig. 2 also comprises a reflector 20 which encircles the amplifying medium and the wall of which 22 is able to reflect this light in a diffusive way. This reflector is preferably quasi-lambertian.

20 The source 16, which opens into the space delimited by the reflector, is orientated so as to send the light beam 18 directly stemming from this source 16 towards the wall 22 of this reflector. This beam 18 then undergoes successive diffusive reflections.

Moreover, the amplifying medium 14 is placed out of this beam directly stemming from the source 16. As a result, this amplifying medium 14 is optically pumped by the sole light diffused by the wall 22 of reflector 20.

30 In the known transverse optical pumping modules, light sources, for example laser diodes, directly emit



in the direction of the amplifying medium. Homogeneity of the pumping can then only result from the sum of the respective contributions of the laser diodes, by a symmetry effect.

5       The present invention goes against this principle: no source used in the invention directly emits its light towards the amplifying medium. This is why the optical pumping method of the invention may be considered as indirect pumping.

10       In the invention, the light flux emitted by each pumping light source all around the amplifying medium is distributed by means of a partly or totally diffusive reflector in order to avoid creating a preferential direction. This source then forms not only  
15       a localized source but an extended source which illuminates the amplifying medium in all directions.

20       It should be noted that quasi homogeneous pumping may be obtained with each source. In the invention, there are therefore less symmetry constraints as in the prior art, both for the mechanical positioning of the sources and for the selective sorting of the latter.

25       It should also be noted that because a diffusive reflector is used, as the amplifying medium is encircled by this reflector, the shape of the latter is not very important: it may be square, polygonal, round or of any other shape.

30       For example, this reflector may be made in ceramic of the SINTOX-A1 (registered trademark) type or in polymer of the SPECTRALON (registered trademark) type or be obtained by means of a surface treatment of a metal wall, for example a treatment of the INFRAGOLD (registered trademark) type during which the metal wall is sandblasted and then a thin gold layer is deposited

thereon.

Let us now consider the transverse optical pumping modules which are schematically illustrated in Figs. 3-5. In each of these modules, a diffusive reflector 20 and an amplifying medium 24 in the shape of a cylindrical rod with a substantially circular base are coaxial and approximately of the same length. These pumping modules are seen in a sectional view perpendicular to axis X which is common to the amplifying medium and to the reflector.

A module according to the invention may be used not only in a laser (strictly speaking) but also in a light-amplifying device where a laser beam crosses an light-amplifying medium for amplifying this beam.

If the modules of Figs. 3-5 are applied to a laser, it is specified that both mirrors of the laser cavity, which delimit this cavity, would be perpendicular to the X axis and respectively placed on either side of the amplifying medium 24.

In the examples of Figs. 3-5, this amplifying medium 24 is solid. It is placed inside a tube 26 which is transparent to the pumping light. In the gap 28 between this tube and the amplifying medium, a cooling liquid transparent to the pumping light is caused to flow by means not shown, in order to cool the amplifying medium.

The reflector 20 encircles the tube 26 and therefore the amplifying medium 24 and the wall 22 of this reflector forms a cylinder with its generatrices parallel to the X axis of the amplifying medium.

In the examples of Figs. 3-5, one or more light sources for optical pumping are used, for example one or more laser diodes with an emission spectrum in

accordance with the absorption spectrum of the amplifying medium.

As an alternative, the light emitted by the laser diodes may be brought inside the pumping chamber delimited by the diffusive reflector, for example by means of optical waveguides, optical fibers or simple slits (made reflecting as regards the pumping light).

The thereby injected light in the pumping chamber is first directed on the diffusive reflecting material, directly without passing through the amplifying medium.

In the example of Fig. 3, the reflector wall is a cylinder with a square base: the four sides of this wall are seen in the figure.

Four optical pumping light sources 30 are used, associated with the four sides respectively. Each of these sources 30 comprises an optical waveguide 32, for example a glass strip, which crosses the reflector parallel to the X axis as seen in Fig. 3.

A first end of this strip 32 opens into the inside of the reflector and is flush with the wall of the latter whereas the second end of the strip opens into the outside of this reflector.

This second end is optically coupled with a laser diode 34 or with a laser diode array parallel to the X axis, which is driven by means not shown.

This diode or this diode array emits the pumping light which is then transferred by the strip and emerges from the first end of this strip so as to illuminate the wall of the reflector.

The inclination  $\beta$  of each strip with respect to the wall and the distance  $d$  of the first corresponding end with respect to an adjacent side of this wall is selected so that the light beam 18 stemming from this

first end illuminates the wall without encountering the amplifying medium 24, the aperture angle  $\alpha$  of this beam (see Fig. 2) being known.

Purely as an indication and by no means as a  
5 limitation, the following are used

- an amplifying rod in Nd:YAG with a diameter of 5 mm and an optical index of 1.82,
- laser diodes with  $40^\circ$  total divergence at half maximum, which are positioned at 0.5 mm from their  
10 respective light waveguides, emit at 808 nm and have a spectral bandwidth of 2 nm at half maximum,
- a glass tube 26 with an internal diameter of 7 mm and an external diameter of 9 mm and an optical index of 1.5, this tube having received an anti-  
15 reflecting treatment on the outside,
- coolant water with an optical index equal to 1.33
- a reflector with a 15 mm sided square wall and having a reflection coefficient of 97.5% and
- 20 - glass optical waveguides with dimensions 1 cm x 1 mm, which have an optical index equal to 1.5 and with first and second ends having received an anti-reflecting treatment.

In the example of Fig. 4, the reflector 20 has a  
25 cylindrical wall with a circular base. Five optical pumping light sources 30 are used.

Each source comprises an optical fiber 36, one end of which is optically coupled with a laser diode 34 driven by means not shown and the other end of which is  
30 located in a rectilinear ferrule 38 which crosses the reflector obliquely (i.e. non-radially) in order to open into the space delimited by this reflector, while being flush with the wall of this reflector.

The light beam 18 directly stemming from the end of the ferrule is seen in the space delimited by the wall 22. This beam further illuminates this wall without encountering the amplifying medium.

5 In the example of Fig. 5, the diffusive reflector 20 has a cylindrical wall 22 with a, for example 5-sided, polygonal base.

Light emitters 40 formed by laser diode arrays which are parallel to the X axis of the amplifying rod 10 24 are used as pumping light sources.

Superpositions and/or stacks of such arrays may also be used.

Five groups of two metal blocks 42 and 44 with two planar faces 46 and 48 respectively, are seen in 15 Fig. 5, which are coplanar and the joining of which forms one of the sides of the wall 22 with a pentagonal base of the module of Fig. 5.

Each laser diode array is located between both metal blocks 42 and 44 of a same group and in the 20 vicinity of the respective faces 46 and 48 of both of these blocks, on the line separating both of these faces.

With this, the laser diodes of this array may be electrically powered by biassing both blocks in an 25 appropriate way, by means in Fig. 5, symbolized by the - and + signs associated with the blocks 42 and 44, respectively.

The existing space between these two blocks is seen in Fig. 5, which is partially occupied by the 30 corresponding array 40. The remainder of this space is filled with an electrically insulating material 50.

It is seen that this space is oblique with respect to the respective planar faces 46 and 48 of both blocks

42 and 44 and that the illumination of the wall of the reflector is again oblique in the case of Fig. 5, as the light beam 18 directly stemming from the array does not encounter the amplifying medium 24.

5       Also, a component 52, made in an electrically insulating material, separates each block, belonging to a determined group of blocks, from a block of the adjacent group in order to prevent any electrical contact between these two blocks.

10       Further, all the faces 46 and 48 are sandblasted and then coated with a thin gold layer in order to obtain the diffusive reflection.

CLAIMS

1. A method for optically pumping a light  
amplifying medium (14, 24), wherein at least one light  
source (14, 30, 40) is used for optically pumping the  
amplifying medium and this amplifying medium is  
5 encircled by a reflector (20), the wall (22) of which  
is able to reflect the light from the source, this  
method being characterized in that the reflector is  
partly or totally diffusive and in that the beam (18)  
directly stemming from the source is sent towards the  
10 wall of the reflector so that this beam undergoes  
successive partly or totally diffusive reflections  
thereon and the amplifying medium is placed out of this  
beam directly stemming from the source so that this  
amplifying medium is optically pumped by the sole light  
15 reflected by the wall of the partly or totally  
diffusive reflector.

2. An optical pumping module comprising a light  
amplifying medium (14, 24), at least one light source  
20 (16, 30, 40) for optically pumping the amplifying  
medium and a reflector (20) which encircles this  
amplifying medium and the wall (22) of which is able to  
reflect the light from the source, this module being  
characterized in that the reflector is partly or  
25 totally diffusive and in that the source is orientated  
so as to send the beam (18) directly stemming from this  
source towards the wall of the reflector so that this  
beam undergoes successive partly or totally diffusive  
reflections thereon and in that the amplifying medium  
30 is placed out of this beam directly stemming from the  
source so that this amplifying medium is optically

pumped by the sole light reflected by the wall of the partly or totally diffusive reflector.

3. The module according to claim 2, wherein the  
5 amplifying medium (24) forms a cylindrical rod with a substantially circular base, the light source (30, 40) is for transverse optical pumping of this medium and the wall (22) of the reflector (20) forms a cylinder with generatrices parallel to the (X) axis of the  
10 amplifying medium.

4. The module according to claim 3, wherein the reflector (20) has substantially the same length as the amplifying medium (24).  
15

5. The module according to any of claims 3 and 4, wherein the base of the cylinder formed by the wall (22) of the reflector is selected from substantially regular polygons, ellipses and circles.  
20

6. The module according to any of claims 3 to 5, wherein the light source is a light emitter (16, 40) and this light emitter is selected from a laser diode, a laser diode array, a row of laser diode arrays, a  
25 stack of laser diode arrays and a combination of this row and this stack, this (or these) array(s) being parallel to the generatrices of the cylinder formed by the wall of the reflector.

7. The module according to any of claims 3 to 6,  
30 further comprising several blocks (42, 44), each block comprising a planar face (46, 48), able to reflect the light from the source in a partly or totally diffusive



way, wherein the base of the cylinder formed by the wall of the reflector is a substantially regular polygon, this wall thereby comprising several sides, each of the latter being formed by two respective planar faces of two adjacent blocks.

8. The module according to claim 7, wherein the light source (40) is placed in a gap formed between two adjacent blocks (42, 44) in such a way that the light emerges from the thereby formed space between the respective planar faces of these two blocks and reaches the wall of the reflector.

9. The module according to claims 6 and 8, wherein both blocks (42, 44) are electrically conducting and the laser diode or the laser diode array(s) (40) are electrically powered via these two blocks.

10. The module according to any of claims 2 to 5, wherein the light source is a light emitter (16, 40).

11. The module according to any of claims 2 to 5, wherein the light source is a light propagation means (32, 36), one end of which is for receiving the light from a light emitter (34) and another end of which is for sending this light towards the wall (22) of the reflector (20).

12. The module according to any of claims 2 to 11, wherein the reflector is quasi-lambertian.

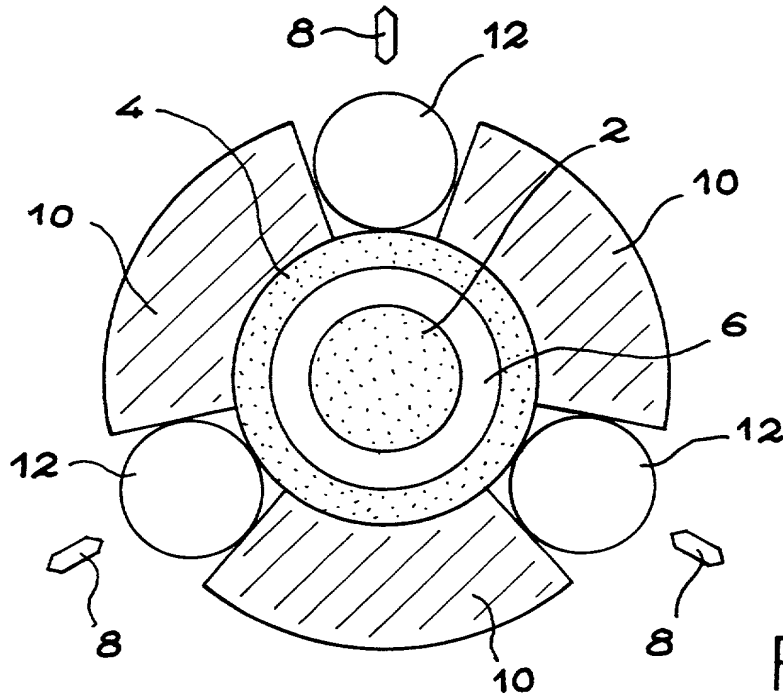


FIG. 1

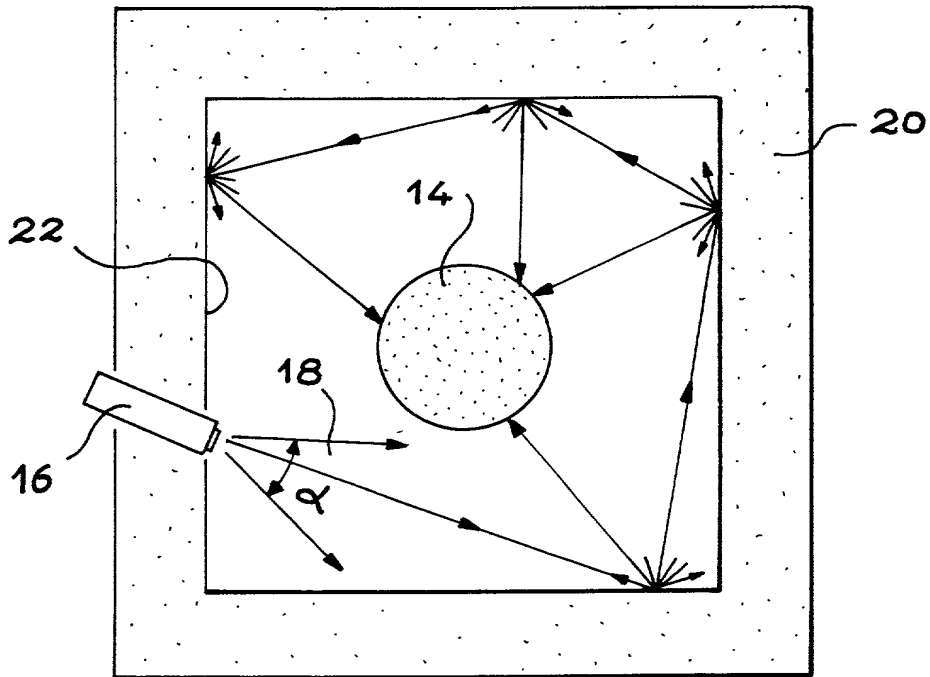


FIG. 2

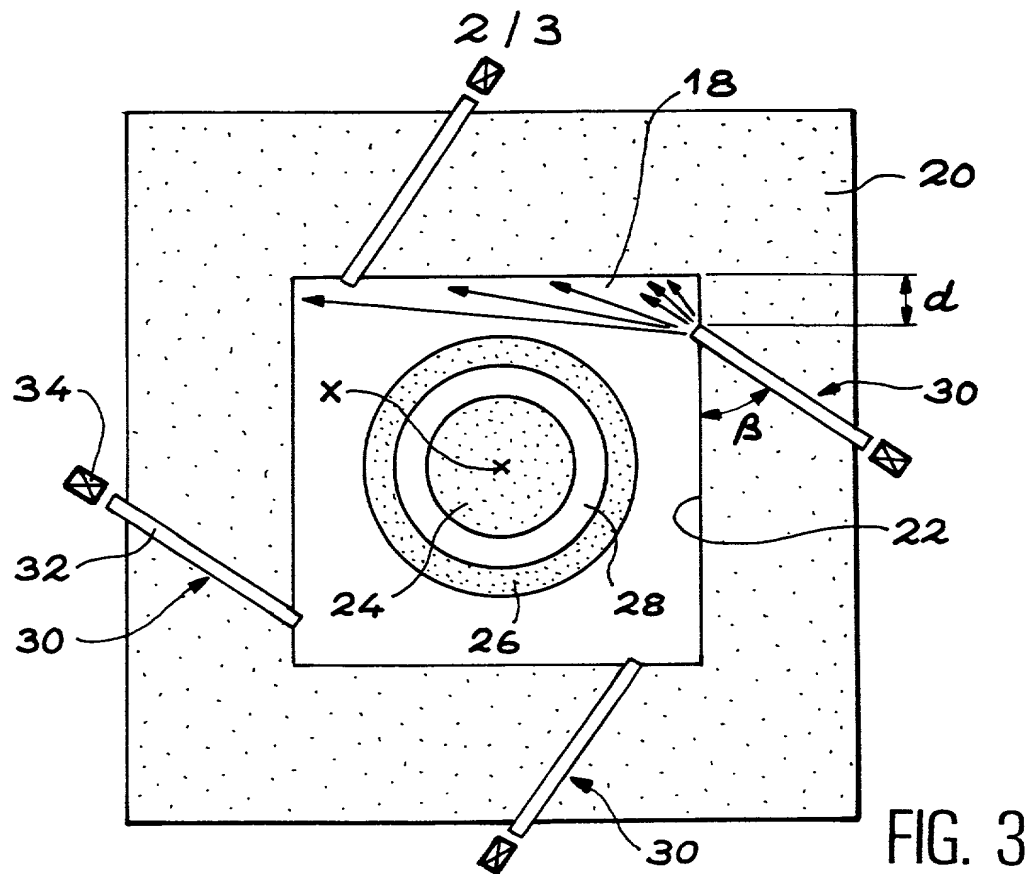


FIG. 3

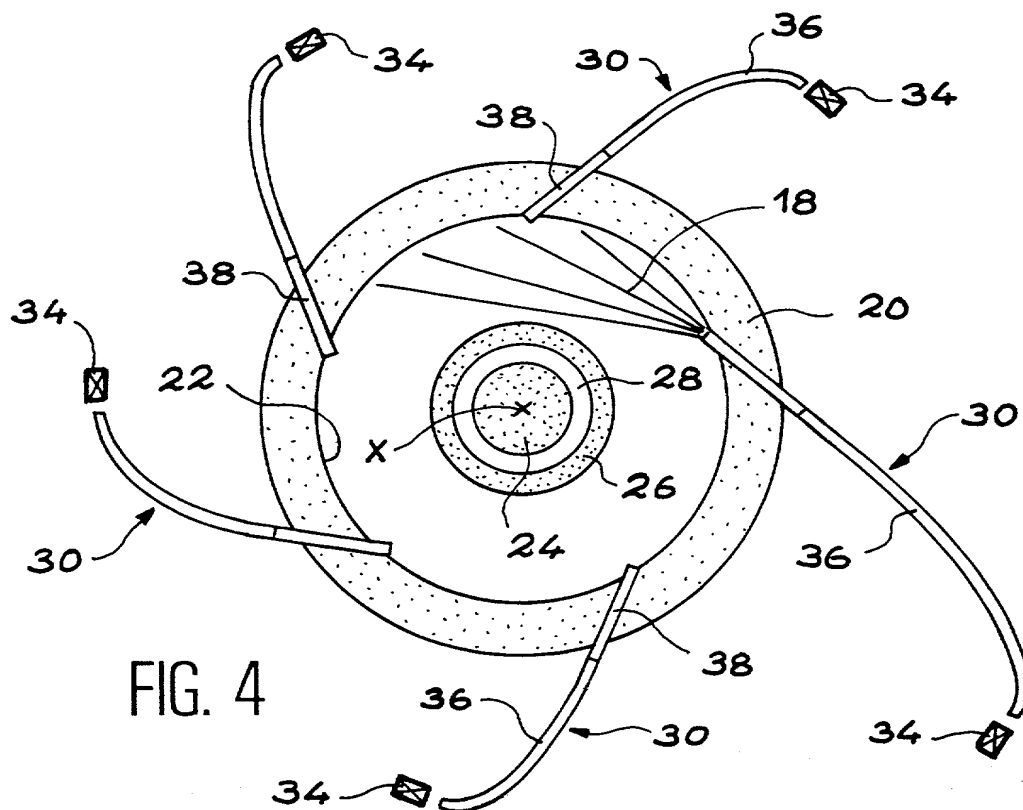


FIG. 4

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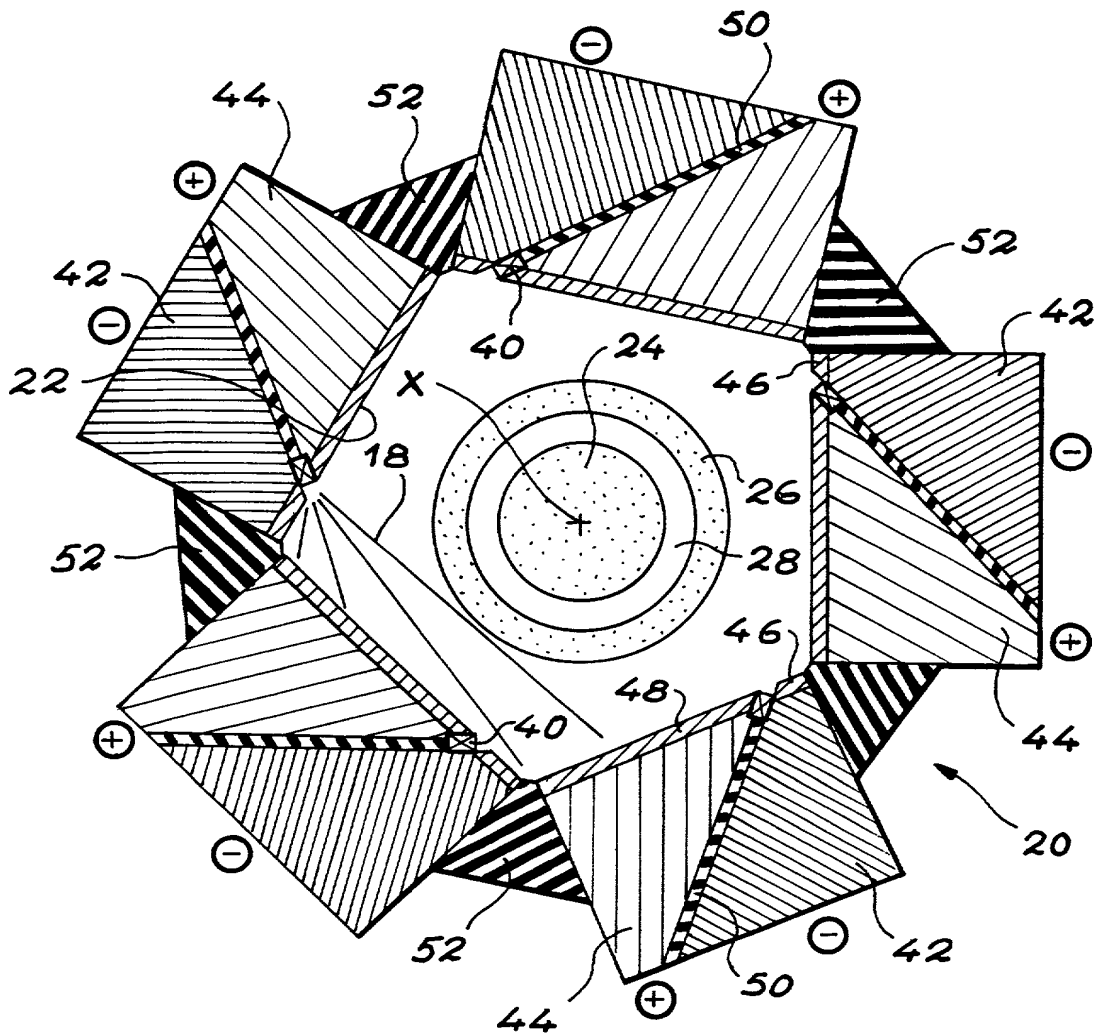


FIG. 5

# Declaration, Power Of Attorney and Petition

Page 1 of 2

WE (I) the undersigned inventor(s), hereby declare(s) that :

My residence, post office address and citizenship are as stated below next to my name,

We (I) believe that we are (I am) the original, first, and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled  
**METHOD FOR OPTICALLY PUMPING A LIGHT-AMPLIFYING MEDIUM AND OPTICAL PUMPING MODULE FOR IMPLEMENTING THIS METHOD.**

the specification of which

- ☐ is attached hereto.
- ☐ was filed on  
 as Application Serial No.  
 and amended on
- ☒ was filed as PCT international application  
 Number PCT/FR00/02142  
 on July 26, 2000  
 and was amended under PCT Article 19  
 on

We (I) hereby state that we (I) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

We (I) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

We (I) hereby claim foreign priority benefits under 35 U.S.C. § 119 (a)-(d) or § 365 (b) of any foreign application(s) for patent or inventor's certificate, or § 365 (a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed. Prior Foreign Application (s)

Application No.	Country	Day/month/Year	Priority Claimed	
99 09720	FRANCE	27 JULY 1999	<input checked="" type="checkbox"/> YES	<input type="checkbox"/> NO
_____	_____	_____	<input type="checkbox"/> YES	<input type="checkbox"/> NO
_____	_____	_____	<input type="checkbox"/> YES	<input type="checkbox"/> NO
_____	_____	_____	<input type="checkbox"/> YES	<input type="checkbox"/> NO

We (I) hereby claim the benefit under Title 35, United States Code, § 119 (e) of any United States provisional application(s) listed below.

\_\_\_\_\_  
(Application Number)

\_\_\_\_\_  
(Filing Date)

\_\_\_\_\_  
(Application Number)

\_\_\_\_\_  
(Filing Date)

We (I) hereby claim the benefit under 35 U.S.C. §120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. § 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR § 1.56 which became available between the filing date of prior application and the national or PCT International filing date of this application.

Application Serial No.

Filing Date

Status (pending, patented,  
abandoned)

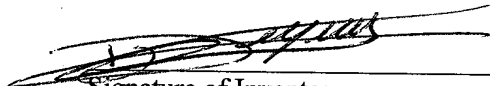
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(21) And we (I) hereby appoint : Norman F. Oblon, Registration Number 24,618; Marvin J. Spivak, Registration Number 24,913; C. Irvin McClelland, Registration Number 21,214; Gregory J. Maier, Registration Number 25,599; Arthur I. Neustadt, Registration Number 24,854; Richard D. Kelly, Registration Number 27,757; James D. Hamilton, Registration Number 28,421; Eckhard H. Kuesters, Registration Number 28,870; Robert T. Pous, Registration Number 29,099; Charles L. Gholz, Registration Number 26,395; Vincent J. Sunderdick, Registration Number 29,004; William E. Beaumont, Registration Number 30,996; Steven B. Kelber, Registration Number 30,073; Robert F. Gnuse, Registration Number 27,295; Jean-Paul Lavalleye, Registration Number 31,451; William B. Walker, Registration Number 22,498; Timothy R. Schwartz, Registration Number 32,171; Stephen G. Baxter, Registration Number 32,884; Martin M., Zoltick, Registration Number 35,745; Robert W. Hahl, Registration Number 33,893; and Richard L. Treanor, Registration Number 36,379; our (my) attorneys, with full powers of substitution and revocation, to prosecute this application and to transact all business in the Patent Office connected therewith; and we (I) hereby request that all correspondence regarding this application be sent to the firm of OBLON, SPIVAK, MCCLELLAND, MAIER & NEUSTADT, P.C., whose post Office Address is : Fourth Floor, 1755 Jefferson Davis Highway, Arlington, Virginia 22202.

We (I) declare that all statements made herein of our (my) own knowledge are true and that all statements made on information and belief are believed to be true ; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such wilful false statements may jeopardise the validity of the application or any patent issuing thereon.

1-00 DUPUY Philippe

\_\_\_\_\_  
NAME OF FIRST SOLE INVENTOR

  
\_\_\_\_\_  
Signature of Inventor

Décember 14, 2001

\_\_\_\_\_  
Date

Residence : 2 rue des Tournelles

92290 CHATENAY-MALABRY FRANCE JPK

Citizen of : FRANCE

Post Office Address : The same as residence